

Evaluation of Drinking Water Needs for Sustainable Supply to the Town of Tioroniaradougou (North of Ivory Coast)

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How to cite this paper: Kouakou, Y.S., Kouadio, A.K.S., Abbey, A.M., Onetie, Z.O. and Soumahoro, B.A. (2025) Evaluation of Drinking Water Needs for Sustainable Supply to the Town of Tioroniaradougou (North of Ivory Coast). *Journal of Environmental Protection*, 16, 891-898.
<https://doi.org/10.4236/jep.2025.169047>

Received: August 25, 2025

Accepted: September 23, 2025

Published: September 26, 2025

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Abstract

This thesis focuses on the assessment of potable water needs in the locality of Tioroniaradougou in Ivory Coast, looking ahead to 2030, 2040, and 2050. In a context of rapid population growth, urbanization, and climate change, the study aims to anticipate the future water requirements of the population and propose sustainable solutions for adequate supply. The methodological approach is based on demographic projections, analysis of water allocations per capita, and the calculation of average, maximum, and peak flow rates. It also includes an analysis of existing infrastructure (boreholes, water towers, distribution network) and a reinforcement strategy based on technical criteria (number of boreholes needed, storage volume, etc.). The results show a growing deficit between demand and current capacities. By 2050, the town will need more than 1100 m³/day, compared to the current capacity of 440 m³/day, with a storage requirement of 822 m³ versus 80 m³ available. But a prospective study on hydraulic infrastructure will be discussed in another publication.

Keywords

Drinking Water, Tioroniaradougou, Population Projections, Water Deficit, Sustainable Supply

1. Introduction

Access to drinking water is a major concern for populations around the world [1]. Particularly in developing regions, population growth, urbanisation and ageing infrastructure pose major challenges. In many places, particularly in sub-Saharan Africa, infrastructure to supply water was built decades ago and is now struggling

to meet the growing needs of populations. The ageing of distribution networks, insufficient available resources and increasing domestic, agricultural and industrial needs are jeopardising the sustainability of drinking water supply systems [2].

Tioroniaradougou, a town in the semi-arid region of northern Côte d'Ivoire, is a stark example of these difficulties. The scarcity of water resources, combined with sustained population growth [3], makes it arduous to supply drinking water. Recurring droughts, which are a real scourge for the region, exacerbate the situation, threatening the food and health security of the populations of Tioroniaradougou [4]. These problems require in-depth studies for the evaluation of actual water needs and the proposal of appropriate strategies to ensure sustainable access to this vital resource. With this in mind, the study will examine two crucial points. First, a study of current water needs will be conducted, followed by a projection of future changes in these needs, taking into account population growth and economic development in the region. But a complementary study on the future of water infrastructure and available water resources will be the subject of another paper.

2. Presentation of the Study Area

Covering an area of 340 km², Tioroniaradougou is a town located in northern Côte d'Ivoire, in the Savanes district, Poro region, near Korhogo (Figure 1). It has a tropical Sudano-Guinean climate with a rainy season from May to October and a dry season from October to April [5]. Its terrain is relatively flat and it is crossed by several rivers, notably the Bandama and its tributaries. The town's population is estimated at 5697 inhabitants in 2021 [3]. The local economy is based mainly on subsistence and cash crop agriculture, with access to drinking water still limited and uneven.

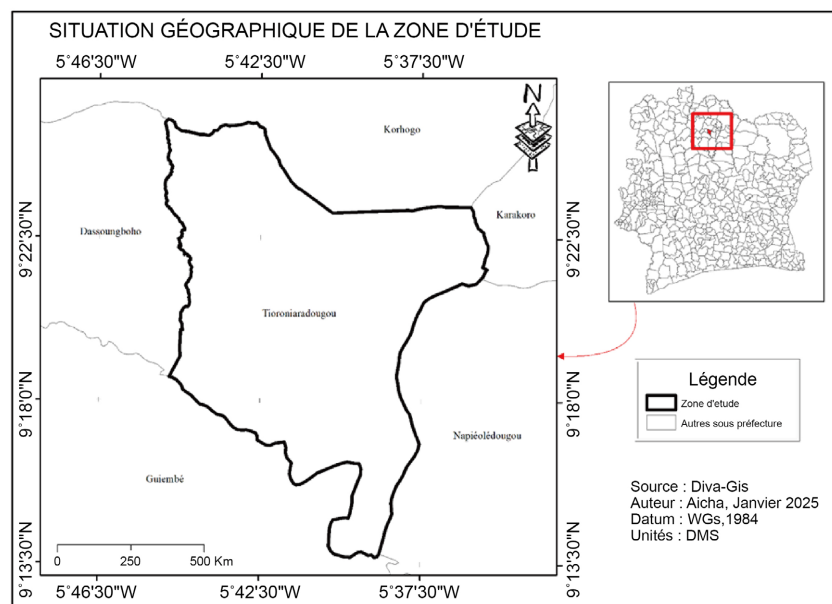


Figure 1. Location of Tioroniaradougou town (North of Ivory Coast) (source: Authors).

3. Materials and Methods

3.1. Materials

The study used various tools to collect data: a GPS device to geolocate water infrastructure, a volumetric meter to quantify the volume of water produced by the borehole in m³/h, and a Photo camera to document the condition of the infrastructure. Specialised software such as QGIS and Origin was used to process the data.

3.2. Methodology

Evaluation Method for Water Dotation

(1) Estimation of population

The population projection is based on the following formula:

$$P_n = P_0 * (1 + \alpha)^{(N_i - N_0)} \quad [6] \quad (1)$$

with:

P_n : Population of year n ;

P_0 : Population in the reference year, taken in 2021, corresponding to the latest population and habitat census in Ivory Coast;

N_i : year i ;

N_0 : reference year;

α : rural growth rate 2.50% [3]

The estimation will be made for the following time horizons:

- Horizon + 0: 2021;
- Horizon + 4: 2025;
- Horizon + 9: 2030;
- Horizon + 19: 2040;
- Horizon + 29: 2050.

(2) Choice of reference demand and increase in water dotation

1) Choice of reference dotation

[7] established a baseline for basic human water dotation, emphasising the importance of ensuring that everyone has enough water for survival, health and hygiene. According to his research, basic water dotation can be divided into several categories:

- Drink: 5 litres
- Hygiene: 20 litres
- Sanitation: 15 litres
- food preparation: 10 litres

2) Method for calculating the increase in the dotation

Water dotation depends on the level of development of the village:

$$D_n = D_0 (1 + a)^n \quad [8] \quad (2)$$

- n : Reference year
- D_n : Water dotation in reference year n (litres/day/inhabitant)

- D_0 : Water dotation in the reference year zero (litres/day/inhabitant)
- a : Increase in dotation (a value of 2 to 5% is accepted)

For this study, we will take a growth rate of 2% in urban areas [1]

(3) Method for calculating average daily consumption ($Q_{m,j}$)

$$Q_{m,j} = (Q_1 + Q_2) \left(\frac{m^3}{j} \right) \quad (\text{OMS, 2015}) \quad (3)$$

Calculation of water requirements for domestic use (Q_1) and social and economic activities (Q_2) Requirements for domestic use (1):

$$Q_1 = P * D \left(\frac{m^3}{j} \right) \quad [7] \quad (4)$$

- Q_1 : domestic water need (m^3/day);
- P : updated population (inhabitants);
- D : average allocation, expressed in $l/j/\text{habt}$.

Social water needs and those of economic activities (2).

For social water needs and those of economic activities, a rate of 10% of domestic needs will be used [8].

$$Q_2 = 0.1 * Q_1 \left(\frac{m^3}{j} \right) \quad (5)$$

(4) Maximum daily flow ($Q_{max,j}$)

$$Q_{max,j} = Q_{m,j} * K_1 \left(\frac{m^3}{j} \right) \quad (6)$$

Avec K_1 = hourly coefficient of variation, equivalent to 1.2 [9]

(5) Point of flow ($Q_{ph,max}$)

$$Q_{ph} = Q_{max,j} K_0 \left(\frac{m^3}{h} \right) \quad (7)$$

(With K_0 hourly variation coefficient = 1.2) [10]

(6) Maximum Daily Flow Rate Produced ($Q_{max,P}$)

$$Q_{max,P} = Q_{max,j} + [20\% Q_{max,j}] \quad (8)$$

Here, a margin of 20% is added to account for eventual losses in the network or unforeseen additional needs [10].

(7) Modelling of water consumption based on population

To analyse the relationship between two variables, such as consumption as a function of population, Origin software was used as a statistical analysis tool.

After obtaining the data (population and consumption), it was entered into Origin in two columns. The software was then used to plot a scatter diagram representing the relationship between the two variables, and then to apply a linear regression using the option "Fit Linear".

The software automatically generates the regression line equation, the coefficients (slope and intercept), and associated statistical values such as standard errors, t-tests, p-values, correlation coefficient (r) and coefficient of determination (R^2). These results allow you to carry out an evaluation of the validity of the model and interpret the effect of the independent variable on the dependent variable. Origin also facilitates the visualisation of results and allows you to make predictions based on the model obtained.

4. Results and Discussion

4.1. Water Needs Evaluation

4.1.1. Evolution of the Population (2014-2050)

The population growth of Tioroniaradougou (**Figure 2**) reveals a significant increase in population, from 3786 inhabitants in 2014 to an estimated 11,659 inhabitants in 2050, or 208%. This trend is consistent with the dynamics observed in other West African cities. For example, [11] reports population growth of 2.8% in Bobo-Dioulasso, while [12] observes an increase of 3.1% in Bamako. Such demographic pressure inevitably leads to an increase in water needs, making it essential to adapt infrastructure to supply water in order to avoid water stress.

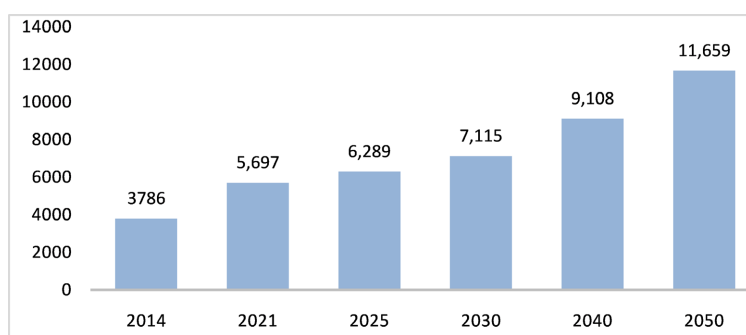


Figure 2. Population growth in Tioroniaradougou (2014-2050).

4.1.2. Evolution of Water Dotation (2014-2050)

The increase in water supply per capita will rise from 44 l/day/capita in 2014 to 89 l/day/capita in 2050, reflecting the expected improvement in living conditions and climate variations. According to [13], this increase is often the result of sustained investment in drinking water infrastructure. [14] also emphasise that urban growth leads to a proportional increase in water demand. This trend implies the need for a gradual strengthening of water services to accompany socio-economic transformations (**Figure 3**).

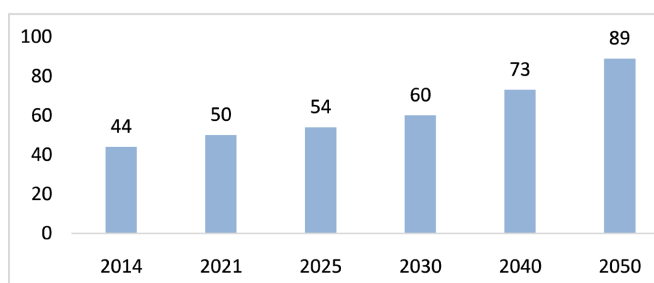


Figure 3. Evolution of water dotation (2014-2050).

4.1.3. Average Daily Consumption

The increase in average daily consumption, reaching 1146 m³/day in 2050 compared to 182 m³/day in 2014, is a clear indicator of the growing pressure on water resources and water infrastructure. [15] point out that this consumption is grow-

ing rapidly in areas where living standards are improving, while [16] show that consumption can increase faster than the population itself. It is therefore essential to anticipate future needs in order to ensure rational and sustainable management of available resources (Figure 4).

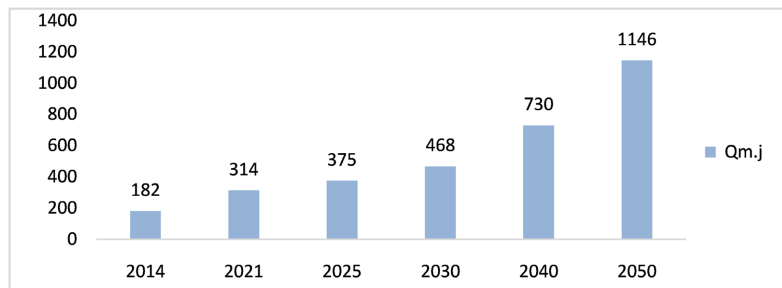


Figure 4. Evolution of average daily consumption.

4.1.4. Maximum Daily Consumption

Maximum daily consumption will reach 1376 m³/day in 2050 (Figure 5). This consumption highlights challenges related to peak demand. According to [17], these peaks can intensify water stress, particularly during periods of heat or drought. [18] add that climatic factors and urban economic fluctuations directly influence maximum daily demand. It is therefore imperative to incorporate these variables into water management planning in order to avoid service disruptions.

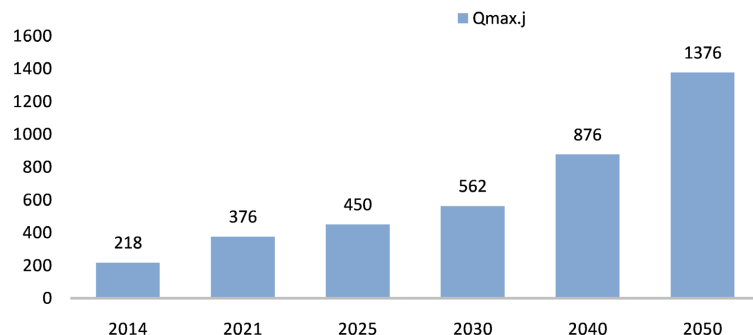


Figure 5. Evolution of maximum daily consumption.

4.1.5. Modelling of Water Consumption Based on Population

The linear relationship obtained between population and water consumption in Tioroniaradougou, through the equation $Y = -374.54734 + 0.12513X$, has a coefficient of determination $R^2 = 0.97$ and a negative ordinate at the origin. This is justified by the fact that this model is intended solely to make forecasts within the observed range of demographic data. This result confirms the existence of a strong link between population growth and increased consumption [19]. Indeed, 97% of the observed variations in water consumption can be explained by population growth. Statistical analysis of the model (F value = 148.17; p-value = 0.00026) confirms its significance. The goodness-of-fit and Pearson's correlation coefficient ($r = 0.98$) show that population growth is a relevant predictor of consumption (Figure 6).

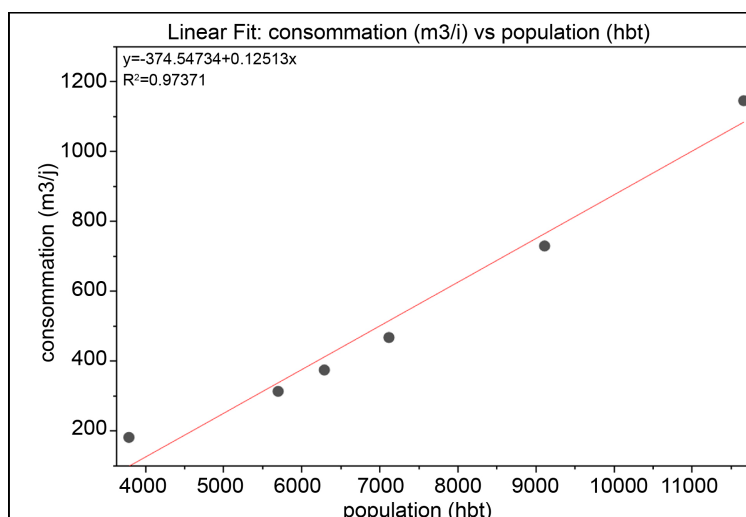


Figure 6. Correlation between water consumption and population.

5. General Conclusion

The study conducted in Tioroniaradougou revealed the scale of the challenges associated with drinking water supply in a context of rapid population growth and low water capacity. Through a rigorous analysis of demographic data, water demand, average daily consumption, and maximum daily consumption will increase significantly by 2050. By the time horizon 2050, these figures will reach 89 l/day/inhabitant, 1146 m³/day and 1376 m³/day respectively. The linear relationship obtained between population and water consumption shows a strong link between population growth and increased consumption, with a coefficient of determination of 97%. These projections for a time horizon of 2050 show a significant increase in water demand, requiring urgent adaptation of infrastructure.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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